

## FLUID EJECTION DEVICE ADHERENCE

### BACKGROUND

**[0001]** A typical inkjet printer usually has a carriage that contains one or more fluid-ejection devices, e.g., print heads, capable of ejecting fluid, such as ink, onto media, such as paper. Print heads usually include a carrier and a fluid-ejecting substrate (or print die), e.g., formed from silicon or the like using semiconductor processing methods, such as photolithography or the like.

**[0002]** The print die is typically affixed to the carrier by an adhesive. In many applications, the carrier includes a plurality of ink delivery channels for directing the ink from the ink reservoir to the print die. A surface of the carrier surrounds each of the ink delivery channels and forms ribs on either side of each of the ink delivery channels. Moreover, print dies usually include a plurality of slots that receive the ink from the ink delivery channels and direct the ink to resistors of the print die. A portion of a surface of the print-die surface surrounds each of the slots and forms ribs on either side of each of the slots. The slots of the print die are typically aligned with the ink delivery channels, and each of the ribs of the print die respectively abuts one of the ribs of the carrier.

**[0003]** To affix a print die to a carrier, an adhesive is typically applied to ribs of the carrier and/or the ribs of the print die, e.g., using a capillary tube of a syringe. The ribs of the print die are aligned with the ribs of the carrier and are pressed into abutment with the ribs of the carrier. One problem with this is that adhesive can be forced from between the abutting ribs and into the ink delivery channels of the carrier and/or the slots of print die, causing a blockage to the flow of ink. To correct for this, the amount of adhesive applied to the ribs is often reduced, which can undesirably allow ink to pass from one slot to another or to leak from the print cartridge. Moreover, print dies are becoming smaller and thus print-die and carrier ribs are becoming smaller. For some applications, print-die and carrier-rib sizes are on the order of, or are smaller than, the diameter of the capillary tubes of the syringes used to apply the adhesives, making it difficult to apply adhesive to the ribs. For many applications, capillary tube diameters cannot be reduced any further because increased fluid flow friction associated with reducing the diameter will make it extremely difficult to produce adhesive flow through the capillary tube.

**[0004]** After the print die is affixed to the carrier, the electrical contacts of the print die are electrically connected to the electrical connectors of the carrier using the electrical interconnects. Since many types of ink are corrosive to the electrical contacts, connectors, and interconnects, an encapsulant is usually disposed on the electrical contacts, connectors, and interconnects to protect them from the ink. However, the electrical contacts, connectors, and interconnects are often located adjacent the orifices, and the encapsulant often flows over the orifices, causing the orifices to become clogged. Moreover, many inkjet printers employ a wiper for wiping ink residue from the orifices to prevent the residue from clogging the orifices or from misdirecting ejected ink drops. However, encapsulants often flow to and solidify at a location such that the encapsulant prevents the wiper from effectively cleaning some of the orifices.

### **SUMMARY**

**[0005]** One embodiment of the present invention provides a method for manufacturing a fluid-ejection device capable of ejecting fluid onto media. The method includes adhering a fluid-ejecting substrate of the fluid-ejection device to a carrier of the fluid-ejection device by drawing an adhesive between the fluid-ejecting substrate and the carrier using capillary action.

### **DESCRIPTION OF THE DRAWINGS**

**[0006]** Figure 1 is a perspective view of a carrier of a fluid-ejection device according to an embodiment of the present invention.

**[0007]** Figure 2 is a cross-sectional view of a fluid-ejection device according to another embodiment of the present invention.

**[0008]** Figure 3 is a cross-sectional view illustrating dispensing an adhesive between a carrier of the fluid-ejection device of Figure 2 and a fluid-ejecting substrate of the fluid-ejection device of Figure 2 according to another embodiment of the present invention.

**[0009]** Figure 4 is a view taken along line 4-4 of Figure 3.

**[0010]** Figure 5 is a view taken along line 5-5 of Figure 3.

**[0011]** Figure 6 is a view taken along line 6-6 of Figure 3.

[0012] Figure 7 is a cross-sectional view illustrating an adhesive disposed between a carrier of the fluid-ejection device of Figure 2 and a fluid-ejecting substrate of the fluid-ejection device of Figure 2 according to another embodiment of the present invention.

[0013] Figure 8 is a view taken along line 8-8 of Figure 7.

[0014] Figure 9 is a view taken along line 9-9 of Figure 7.

[0015] Figure 10 is a cross-sectional view illustrating dispensing an adhesive between a carrier of the fluid-ejection device of Figure 2 and a fluid-ejecting substrate of the fluid-ejection device of Figure 2 according to another embodiment of the present invention.

[0016] Figure 11 is a view taken along line 11-11 of Figure 10.

[0017] Figure 12 is a view taken along line 12-12 of Figure 10.

[0018] Figure 13 is a perspective view illustrating a carrier of a fluid ejection device according to another embodiment of the present invention.

[0019] Figure 14 is a perspective view illustrating an adhesive disposed in a moat of the carrier of Figure 13.

[0020] Figure 15 is a perspective view illustrating a fluid-ejection device according to another embodiment of the present invention.

[0021] Figure 16 is a cross-sectional view illustrating positioning a fluid-ejecting substrate of a fluid-ejection device on a carrier of the fluid-ejection device according to another embodiment of the present invention.

[0022] Figures 17 and 18 are cross-sectional views illustrating an adhesive being drawn between the fluid-ejecting substrate of Figure 16 and the carrier of Figure 16 according to another embodiment of the present invention.

[0023] Figure 19 is a perspective view of a fluid-ejection device according to another embodiment of the present invention.

[0024] Figure 20 is an enlarged view of region 2000 of Figure 19.

[0025] Figure 21 is a view taken along line 21-21 of Figure 20.

[0026] Figure 22 is a view taken along line 22-22 of Figure 20 illustrating another embodiment of the present invention.

**[0027]** Figure 23 illustrates channels disposed on a surface of a fluid-ejecting substrate of the fluid-ejection device of Figure 19 according to another embodiment of the present invention.

**[0028]** Figure 24 illustrates a channel disposed on a surface of a fluid-ejecting substrate of the fluid-ejection device of Figure 19 according to yet another embodiment of the present invention.

**[0029]** Figure 25 illustrates a fluid-ejection cartridge according to another embodiment of the present invention.

**[0030]** Figure 26 illustrates a fluid deposition system according to another embodiment of the present invention.

### **DETAILED DESCRIPTION**

**[0031]** In the following detailed description of the present embodiments, reference is made to the accompanying drawings that form a part hereof, and in which is shown by way of illustration specific embodiments in which the invention may be practiced. These embodiments are described in sufficient detail to enable those skilled in the art to practice the invention, and it is to be understood that other embodiments may be utilized and that process, electrical or mechanical changes may be made without departing from the scope of the present invention. The following detailed description is, therefore, not to be taken in a limiting sense, and the scope of the present invention is defined only by the appended claims and equivalents thereof.

**[0032]** Figure 1 illustrates a carrier 100 of a fluid ejection device, such as a print head, according to an embodiment of the present invention. Carrier 100 has a recess (or well) 102 in a surface 104. A surface 110 and walls 112 bound recess 102. For one embodiment, surface 110 is substantially parallel to surface 104, and walls 112 are substantially perpendicular to surfaces 104 and 110. In other embodiments, walls 112 are inclined between surfaces 102 and 110. For one embodiment, a flow passage 114 passes through a portion of carrier 100 and opens into recess 102 at one of walls 112. Surface 110 surrounds flow channels 116, e.g., ink delivery channels, of carrier 100 that open into recess 102 at surface 110. Carrier 100 can be fabricated from plastic, ceramic, silicon, or the like.

**[0033]** Figures 2-12 illustrate adhering a fluid-ejecting substrate 202 (e.g., a print-head die or substrate) to carrier 100 to form a fluid-ejection device 200 according to an

embodiment of the present invention. Fluid-ejection device 200 is capable of ejecting fluid, e.g., ink, onto media, such as paper. For one embodiment, a gap 204 is formed between fluid-ejecting substrate 202 and carrier 100 by disposing spacers (or standoffs) 206 between a surface 212 fluid-ejecting substrate 202 and surface 110 of carrier 100. Examples of spacers 206 include permanent shims, removable shims, thin films disposed on carrier 100 by thin-film processing techniques, standoffs integral with carrier 100 formed by plastic injection or the like, small adhesive dots cured in place, metal posts, solder bumps, polyimide tape, etc. For some embodiments, naturally occurring projections, e.g., that constitute roughness, on a surface 212 fluid-ejecting substrate 202 and surface 110 of carrier 100 can form gap 204. In some embodiments, gap 204 ranges from about 0.5 to about 150 microns.

**[0034]** Fluid-ejecting substrate 202 includes slots 210 (Figure 4) that respectively align with channels 116 (Figure 5) when fluid-ejecting substrate 202 is disposed on carrier 100, as shown in Figure 6. Moreover, surface 212 of fluid-ejecting substrate 202 surrounds each of slots 210, as shown in Figure 4. For various embodiments, fluid-ejecting substrate 202 is formed from a semiconductor material, such as silicon or the like using semiconductor processing methods, such as photolithography or the like. Note that fluid-ejecting substrate 202 is shown as a dashed line on carrier 100 in Figures 5, 9, and 12 to illustrate positioning of fluid-ejecting substrate 202 on carrier 100.

**[0035]** An adhesive 220 is disposed between fluid-ejecting substrate 202 and carrier 100 for adhering fluid-ejecting substrate 202 to carrier 100. For one embodiment, adhesive 220 is directed into recess 102 through flow passage 114, as shown in Figure 2. In other embodiments, adhesive 220 is dispensed into recess using a syringe or the like. One suitable adhesive is available from Emerson & Cuming, Inc., Billerica, MA, USA, as part numbers E1172 or E1216.

**[0036]** For one embodiment, capillary action draws adhesive 220 through gap 204 between fluid-ejecting substrate 202 and carrier 100 from one of edges 222 of fluid-ejecting substrate 202, as illustrated in Figures 3-5. For other embodiments, capillary action draws adhesive 220 through gap 204 from all of edges 222, as illustrated in Figures 10-12. Adhesive 220 flows over surface 212 of fluid-ejecting substrate 202 without flowing into slots 210. Adhesive 220 also flows over surface 110 of carrier 100 without flowing into channels 116.

[0037] Adhesive 220 continues to flow on surfaces 110 and 212 until surface 212 and the portion of surface 110 corresponding to surface 212 are coated with adhesive 220, as shown in Figures 7-9 for the situation of Figures 3-5, i.e., where adhesive 220 is drawn from one of edges 222. For the situation of Figures 10-12, i.e., where adhesive 220 is drawn from all of edges 222, surfaces 110 and 212, for one embodiment, will be completely coated with adhesive 220 when adhesive 220 stops flowing. At this point, adhesive 220 is allowed to cure and/or solidify, thereby adhering fluid-ejecting substrate 202 to carrier 100.

[0038] An attractive force between molecules of adhesive 220 and surfaces 110 and 212 causes adhesive 220 to wet surfaces 110 and 212 and produces the capillary action that draws adhesive 220 through gap 204. The surface tension of adhesive 220 acts to prevent adhesive 220 from flowing into channels 116 and slots 210.

[0039] For one embodiment, the surface tension of adhesive 220 provides a self-alignment feature. That is, as adhesive 220 wets surfaces 110 and 212, the surface tension causes wetted surfaces 110 and 212 to align with each other, causing slots 210 to respectively self-align with channels 116.

[0040] For some embodiments, before drawing adhesive 220 through gap 204, adhesive 220, fluid-ejecting substrate 202, and carrier 100 are heated to a temperature, e.g., about 80°C, where the viscosity of adhesive 220 is such that the adhesive 220 flows with less resistance through gap 204 when drawn therethrough. For some embodiments, the viscosity of adhesive 220, when heated, ranges from about 30 to about 2500 centipoise. Heating can also improve the wetting of surfaces 110 and 212 by adhesive 220, thereby enabling adhesive 220 to flow better through gap 204.

[0041] Figure 13 illustrates a carrier 1300 of a fluid ejection device according to another embodiment of the present invention. Elements common to Figures 1 and 13 are numbered as in Figure 1 and are as described above. Carrier 1300 includes a channel (or moat) 1310 disposed around surface 110 of carrier 1300. For some embodiments, moat 1310 and surface 110 are located within in a recess (or well), such as shown in Figure 1 for carrier 100 and as described above. For other embodiments, the moat is located below surface 110 of carrier 1300, as shown in Figure 13.

[0042] Figures 14-18 illustrate adhering fluid-ejecting substrate 202 to carrier 1300 to form a fluid-ejection device 1500 according to another embodiment of the present invention.

Elements common to Figures 2-12 and Figures 14-18 are numbered as in Figures 2-12 and are as described above. Adhesive 220 is disposed in moat 1310 as shown in Figure 14. For one embodiment, a portion of adhesive 220 protrudes above surface 110 of carrier 1300, as shown in Figure 16, due to the surface tension of adhesive 220. For another embodiment, adhesive 220 is directed into moat 1310 through a flow passage, such as flow passage 114 shown in Figure 2. In other embodiments, adhesive 220 may be dispensed into moat 1310 using a syringe or the like.

**[0043]** Fluid-ejecting substrate 202 is positioned on spacers 206 to form gap 204, as shown in Figures 15-18. When fluid-ejecting substrate 202 contacts adhesive 220, adhesive is drawn into gap 204 from all of edges 222 of fluid-ejecting substrate 202 by capillary action, e.g., as described above and shown in Figures 10-12 for fluid-ejection device 200. For one embodiment, the surface tension of adhesive 220 causes slots 210 to respectively self-align with channels 116, as described above.

**[0044]** Figure 19 is a perspective view of a fluid-ejection device 1900. Elements common to Figures 1-12 and Figure 19 are numbered as in Figures 1-12. Fluid-ejection device 1900 includes fluid-ejecting substrate 202 disposed on a carrier 1902. For one embodiment, carrier 1902 is as described above for carrier 100 or carrier 1300, and fluid-ejecting substrate 202 is adhered to carrier 1902 as described above for forming fluid-ejection device 200 or 1500. For one embodiment, fluid-ejecting substrate 202 includes orifices 214 in a surface 216 of fluid-ejecting substrate 202. Surface 216 is opposite surface 212, as shown in Figure 3. For one embodiment, resistors 217 are disposed in fluid-ejecting substrate 202 adjacent each of orifices 214, as shown in Figures 25 and 26.

**[0045]** After adhering fluid-ejecting substrate 202 to carrier 1902, electrical contacts 250 of fluid-ejecting substrate 202 are electrically connected to electrical connectors 1950 of carrier 1902 using electrical interconnects 252, such as wires. Electrical contacts 250 are electrically connected to resistors 217 of fluid-ejecting substrate 202. An encapsulant 254 is disposed on electrical contacts 250, electrical connectors 1950, and electrical interconnects 252 to protect them from fluid that is ejected through orifices 214. Electrical connectors 1950 are electrically connected to an electrical terminal 1960. Electrical terminal 1960 is connected to a power source (not shown), e.g., included as a part of a printer (not shown). Electrical signals for energizing resistors 217 are conveyed from the power source to resistors

217 via electrical terminal 1960, electrical connectors 1950, electrical interconnects 252, and electrical contacts 250.

[0046] Channels 260 are disposed in surface 216 of fluid-ejecting substrate 202 between electrical connectors 250 and orifices 214, as shown in Figures 19 and 20, e.g., using semiconductor fabrication methods, such as etching, photolithography, or the like. Each of ribs 262 respectively separates successively adjacent channels 260. Ribs 262 extend from a base 264 of each of channels 260 to surface 216, as shown in Figures 21 and 22.

[0047] As encapsulant 254 is dispensed on electrical contacts 250, electrical connectors 150, and electrical interconnects 252 by directing a flow of encapsulant 254 thereon, e.g., using a syringe or the like, encapsulant 254 can spread (or flow) toward orifices 214. As encapsulant 254 flows toward orifices 214, encapsulant 254 flows over ribs 262 and in channels 260, as shown in Figures 20 and 21. This acts to prevent encapsulant 254 from spreading, e.g., beyond a distance  $d$  from orifices 214 located closest to channels 260, as shown in Figure 20.

[0048] For one embodiment, encapsulant 254 includes resin and filler components. For another embodiment, the filler includes particles of silica, alumina, calcium carbonate, fumed  $\text{SiO}_2$  of a controlled particle size, etc. For other embodiments, filler particle sizes can range from about 1 micron to about 50 microns. The filler acts generally to increase the viscosity of encapsulant 254. That is, the higher the filler concentration, the more viscous the encapsulant 254. For one embodiment, and as best understood with reference to Figure 20, an attractive force between molecules of encapsulant 254 and ribs 262 produces capillary action that draws the resin from encapsulant 254, causing the resin to flow through channels 260 substantially parallel to surface 216 and away from a boundary (or front) 266 of encapsulant 254, as indicated by arrow 268 in Figure 20. This increases the filler concentration and thus the viscosity of encapsulant 254 adjacent the boundary 266. The increased viscosity acts to control the spread of encapsulant 254. In one embodiment, the increased viscosity acts to stop the flow of encapsulant 254 at the distance  $d$  from orifices 214 located closest to channels 260. In another embodiment, the increased viscosity acts to slow the flow of encapsulant 254 so that encapsulant 254 solidifies at the distance  $d$  from orifices 214 located closest to channels 260.

[0049] For some embodiments, and as best understood with reference to Figure 22, ribs 262 are spaced so that the width  $w$  of each of channels 260 is too small for encapsulant 254 to

flow into channels 260, e.g., owing to surface tension, viscosity, etc. of encapsulant 254. In these embodiments, encapsulant 254 flows over segments of surface 216 (i.e., segments corresponding to surfaces of the ribs 262) located between channels 260 toward orifices 214, as indicated by arrow 268 in Figure 22. Further, in these embodiments, capillary action draws resin away from a boundary 270 of encapsulant 254 that is substantially parallel to surface 216 into channels 260 toward base 264 so that the resin flows substantially perpendicular to surface 216, as indicated by arrows 272 in Figure 22. This increases the filler concentration and thus the viscosity of encapsulant 254 adjacent the boundary 270. The increased viscosity acts to control the spread of encapsulant 254 by slowing or stopping the flow of encapsulant 254.

**[0050]** For another embodiment, channels 2360 are disposed in surface 216 of fluid-ejecting substrate 202 between electrical connectors 250 and orifices 214, as shown in Figure 23. Channels 2360 include channel segments 2362 and 2364 connected by a taper 2366. In this way, channel segment 2362 has a larger flow cross-section than channel segment 2364. For one embodiment, channel segment 2364 is sized so that channel segment 2364 acts to prevent particles of the filler of encapsulant 254 from flowing through channel segment 2364. For another embodiment, this is accomplished by making the flow cross-section of channel segment 2364 smaller than the particles of the filler. For other embodiments, an inlet 2368 to channel segment 2364 is at the distance  $d$  from orifices 214 located closest to channels 2360.

**[0051]** Encapsulant 254 flows over surface 216 in the vicinity of channels 2360 and through channel segments 2362. When encapsulant 254 encounters channel segment 2364, the filler stops generally at inlet 2368, and the resin is drawn through channel segment 2364 by capillary action. This increases the filler concentration and thus the viscosity of encapsulant 254 adjacent a boundary 2370 of encapsulant 254. Channel segments 2364 and the increased viscosity act to control the spread of encapsulant 254 by slowing or stopping the flow of encapsulant 254. In particular, for one embodiment, channel segments 2364 and the increased viscosity act to stop the flow of encapsulant 254 at the distance  $d$ , where, in other embodiments, encapsulant 254 solidifies.

**[0052]** In another embodiment, the channels disposed in surface 216 of fluid-ejecting substrate 202 are as shown for channel 2460 in Figure 24. Channel 2460 includes channel segments 2462 and 2464 connected by a step 2466. In this way, channel segment 2462 has a larger flow cross-section than channel segment 2464. For one embodiment, channel segment

2464 is sized so that channel segment 2464 acts to prevent particles of the filler of encapsulant 254 from flowing through channel segment 2464. For another embodiment, this is accomplished by making the flow cross-section of channel segment 2464 smaller than the particles of the filler. For other embodiments, an inlet 2468 to channel segment 2462 is at the distance  $d$  from orifices 214 located closest to the channels disposed in surface 216. Channel 2460 functions generally as described above for channels 2360. That is, when encapsulant 254 encounters channel segment 2464, the filler stops generally at inlet 2468, and the resin is drawn through channel segment 2464 by capillary action.

[0053] For one embodiment, the resin separates from the filler and continues to flow ahead of the concentrated filler region until the capillary force reaches equilibrium, thereby stopping resin flow. In effect, there is a resin/filler gradient, and the resin advances to create a thin, tapered layer that eventually stops because there is no additional resin supply.

[0054] Figure 25 illustrates a fluid-ejection cartridge 2500, e.g., a print cartridge, according to another embodiment of the present invention. Elements common to Figures 1-19 and Figure 25 are as described above for Figures 1-19. Fluid-ejection cartridge 2500 includes a fluid reservoir 2510, e.g., an ink reservoir, integral with a carrier 2530 of a fluid-ejection device 2540. For one embodiment, carrier 2530 is as described for carriers 100, 1300, or 1902, respectively of Figures 1, 13, and 19. For another embodiment, fluid-ejection device 2540 is as described above for fluid-ejection devices 200, 1500, or 1900, respectively of Figures 2, 15, and 19 and thus includes the fluid-ejecting substrate 202 described above. A flow passage 2550 fluidly couples fluid-ejection device 2540 to reservoir 2510.

[0055] In operation, fluid reservoir 2510 supplies fluid, such as ink, to fluid-ejection device 2540. Channels of carrier 2530, such as channels 116 of carrier 100 or carrier 1300, deliver the fluid to slots 210 of fluid-ejecting substrate 202. The fluid is channeled from slots 210 to resistors 217. Resistors 217 are selectively energized to rapidly heat the fluid, causing the fluid to be expelled through orifices 214 in the form of droplets 2560. For some embodiments, droplets 2560 are deposited onto a medium 2570, e.g., paper, as fluid-ejection cartridge 2500 is fixedly or movably positioned adjacent medium 2570 in an imaging device (not shown), such as a printer, fax machine, or the like.

[0056] Figure 26 illustrates a fluid deposition system 2600, e.g., an ink deposition system, according to another embodiment of the present invention. Elements common to Figures 1-19 and Figure 26 are as described above for Figures 1-19. Fluid deposition system

2600 includes a fluid-ejection device 2610 fluidly coupled to an outlet port 2620 of a fluid reservoir 2630, e.g., ink reservoir, by a flexible conduit 2640, such as plastic or rubber tubing or the like. For one embodiment, fluid-ejection device 2610 includes a carrier 2650 that for another embodiment is as described for carriers 100, 1300, or 1902, respectively of Figures 1, 13, and 19. For other embodiments, fluid-ejection device 2610 is as described above for fluid-ejection devices 200, 1500, or 1900, respectively of Figures 2, 15, and 19 and thus includes the fluid-ejecting substrate 202 described above.

**[0057]** In operation, fluid reservoir 2630 supplies fluid, such as ink, to fluid-ejection device 2610 via flexible conduit 2640. Channels of carrier 2650, such as channels 116 of carrier 100 or carrier 1300, deliver the fluid to slots 210 of fluid-ejecting substrate 202. The fluid is channeled from slots 210 to resistors 217. Resistors 217 are selectively energized to rapidly heat the fluid, causing the fluid to be expelled through orifices 214 in the form of droplets 2660. For some embodiments, droplets 2660 are deposited onto a medium 2670, e.g., paper, as fluid-ejection device 2610 is fixedly or movably positioned adjacent medium 2670 while fluid reservoir 2630 remains stationary. Flexible conduit 2640 enables fluid-ejection device 2610 to move relative to fluid reservoir 2630 in some embodiments.

## CONCLUSION

**[0058]** Although specific embodiments have been illustrated and described herein, it will be appreciated by those of ordinary skill in the art that any arrangement that is calculated to achieve the same purpose may be substituted for the specific embodiments shown. Many adaptations of the invention will be apparent to those of ordinary skill in the art. Accordingly, this application is intended to cover any adaptations or variations of the invention. It is manifestly intended that this invention be limited only by the following claims and equivalents thereof.